



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>5</sup> :

A61B 17/58

A1

(11) International Publication Number:

WO 90/07304

(43) International Publication Date:

12 July 1990 (12.07.90)

(21) International Application Number: PCT/FI89/00236

(22) International Filing Date: 20 December 1989 (20.12.89)

(30) Priority data:

885981

23 December 1988 (23.12.88) FI

(71) Applicant (for all designated States except US): BIOCON OY [FI/FI]; Runeberginkatu 3 A, SF-33710 Tampere (FI).

(72) Inventors; and

(75) Inventors/Applicants (for US only) : POHJONEN, Timo [FI/FI]; Nosturinraitti 2 B 17, SF-33720 Tampere (FI). TÖRMÄLÄ, Pertti [FI/FI]; Runeberginkatu 3 A, SF-33710 Tampere (FI). VAINIONPÄÄ, Seppo [FI/FI]; Orapihlajatie 21-27 B 12, SF-00320 Helsinki (FI). TAMMINMAKI, Markku [FI/FI]; Kukkolankatu 23 B 12, SF-33400 Tampere (FI).

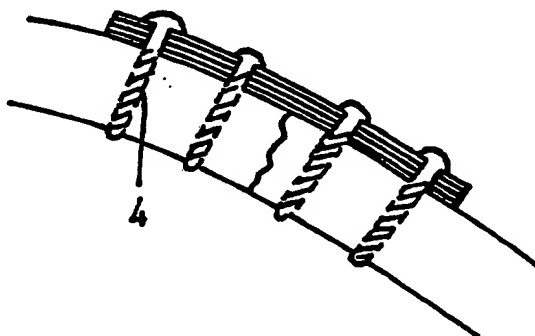
(74) Agent: KAHILAINEN, Hannu; Tampereen patenttitoimisto Oy, Kanslerinkatu 6, SF-33720 Tampere (FI).

(81) Designated States: AT (European patent), AU, BE (European patent), CH (European patent), DE (European patent), ES (European patent), FI, FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US.

Published

With international search report.

(54) Title: POLYMERIC FIXATION PLATE FOR SURGICAL USE



## (57) Abstract

This invention describes a multilayer plate for fixation of bone fractures, osteotomies, arthrodeses or corresponding or for fixation of a ligament, tendon or connective tissue on the bone, which multilayer plate is fixed on the bone at least with one fixing device, like screw, rod, clamp or corresponding and the said multilayer plate comprises at least two essentially superimposed plates, which have been manufactured of polymer, copolymer, polymer mixture or polymer composite and which multilayer plate be bent in operation room by hand or by means of suitable bending instrument to follow the form of the bone surface. The single plates of the multilayer plate can glide in relation to each other in beginning of their surgical installation but they are locked to their place during the fixation process. Accordingly the multilayer plate creates an exact and strong fixation of a bone fracture without the need to heat the plate system for bending it.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MG	Madagascar
AU	Australia	FI	Finland	ML	Mali
BB	Barbados	FR	France	MR	Mauritania
BE	Belgium	GA	Gabon	MW	Malawi
BF	Burkina Faso	GB	United Kingdom	NL	Netherlands
BG	Bulgaria	HU	Hungary	NO	Norway
BJ	Benin	IT	Italy	RO	Romania
BR	Brazil	JP	Japan	SD	Sudan
CA	Canada	KP	Democratic People's Republic of Korea	SE	Sweden
CF	Central African Republic	KR	Republic of Korea	SN	Senegal
CG	Congo	LI	Liechtenstein	SU	Soviet Union
CH	Switzerland	LK	Sri Lanka	TD	Chad
CM	Cameroon	LU	Luxembourg	TG	Togo
DE	Germany, Federal Republic of	MC	Monaco	US	United States of America
DK	Denmark				

## Polymeric fixation plate for surgical use

This invention describes a fixation device, which has been manufactured of a polymer, polymer mixture, 5 copolymer or polymer composite and which is meant for fixation of bone fractures, osteotomies or arthrodeses. The device has been defined in more detail in the preamble of claim 1.

10 In orthopaedics and traumatology it is well known to use metallic plates for fixation of bone fractures, osteotomies or arthrodeses, in such a way that the plate bridges fracture-, osteotomy- or arthrodesis line and the plate is fixed into the bone with screws, 15 bolts, rivets, rods, clamps or other corresponding fixation devices (see e.g. J. Schatzker and M. Tile "The Rationale of Operative Fracture Care", Springer, Berlin, 1987).

20 Figure 1 shows schematically as a side view in cross-section how metallic plate 1 immobilises the fracture 3 in a bone 2 when the plate has been fixed into bone on both sides of the fracture with fixation devices like screws 4. Plate - screw combination maintains 25 the contact between the bone parts and makes healing possible.

Metallic plates have, however, some negative properties. Metals are biomechanically too stiff 30 materials (elastic modulus typically 100-200 GPa) in comparison to bone (elastic modulus typically 1-20 GPa). Therefore the metallic plate fixation protects bone too effectively against outer stresses. This leads to a so-called primary healing, which is slower 35 than the healing with so-called callus mechanism, which happens with plates more flexible than the traditional metallic plates (see e.g. S.L.-Y. Woo, W.H. Akeson and R.D. Coutss in Perspectives on Biomaterials", O.C.C. Lind and E.Y.S. Chao (eds.),

Elsevier, Amsterdam, 1986, pp. 223-244). Additionally the stiff metallic plate can lead to the increase of bone porosity.

- 5    Metallic corrosion can also often cause pains to patients. Therefore, after healing, the metallic plates must be removed in a second operation. After that the refracture of porous bone is possible.
- 10    An advantage of metallic plates is that they can easily be bend according to the form of the bone surface, which facilitates the creation of exact reduction. The bending can be done in an operation room with specific instruments. This is possible
- 15    because fixation metals have strong plastic deformation capacity.

- Many researchers have tried to develop polymeric fixation plates, especially of absorbable polymers
- 20    and of polymer composites to eliminate the disadvantages of the metallic plates (the too high modulus, the increase of bone porosity, the metallic corrosion and the need of removal operation). In literature there are known for example polylactide
- 25    plates (see e.g. L. Getter et al. "A biodegradable intraosseous appliance in the treatment of mandibular fractures", J. Oral. Surg. 30 (1972) 344-348), lactide plates reinforced with ceramic fibers (see e.g. D. Lewis et al. "Absorbable fixation plates with fiber
- 30    reinforcement", 7th Ann. Meeting Biomater., Troy N.Y., 1981, p. 61) and lactide plates reinforced with carbon fibers (see e.g. H. Alexander et al. "Internal fracture fixation with partially degradable plates", Bioengineering - 9th Conf. Elmsford, New
- 35    York, 1981, pp. 115-118).

The most important weakness of known polymeric or polymer composite fixation plates is their poor plastic

deformation in bending. It is possible to bend the plates but the deformation of polymers and polymer composites is at or near the room temperature mainly elastic and viscoelastic deformation, which is at least partially reversible. Therefore it is not possible to bend the plates at operation room temperature in a controlled way into a permanent form following the features of the bone surface. Only when the polymer or polymer composite plate is heated to a temperature  $T > T_g$ , where  $T_g$  is the glass transition temperature of the polymer, it is possible to create plate the necessary strong plastic deformation into the plate (see e.g. J. Eitenmüller et al. "Treatment of ankle fractures with complete biodegradable plates and screws of highn molecular weight polylactide", Trans. 3rd World Biomater. Congr., Kyoto, Japan, 1988, p. 195). The heating demands, however, special heating devices in the operation room. The plate must be heated, then bending as hot and it must be cooled before fixation on the bone. This makes the operation slow and complicated.

In this invention it has been found unexpectedly that when one uses a plate in accordance with the characteristic part of claim 1 instead one stiff polymeric and polymer composite plate at least two flexible plates, which essentially one on the other form a plate-like fixation device (multilayer plate) and which plates have such a thickness that they can be bend by hand and/or by means of a suitable bending instrument at room temperature, it is possible to eliminate the problems which are typical for the known polymeric or polymer composite fixation plates.

It is typical for the multilayer plate of the invention that it can before fixation easily be bent by hand or by a bending instrument, because the single plates of the multilayer plate glide in respect to each other.

Therefore it is possible to bend such multilayer plate at room or body temperature in operation room conditions on the surface of the uncovered fractured bone to follow exactly the features of the bone.

5    Thereafter the multilayer plate can be fixed on the bone surface in the bended form temporarily e.g. by means of metallic clamps. Thereafter the bended multilayer plate can be locked into this desired form by drilling through the multilayer plate and the bone

10   below it a suitable amount of drill holes and by fixing the bended multilayer plate into bone with screws, bolts, rivets, clamps etc. When the multilayer plate has been fixed tightly on the bone surface, it retains its bended form. The single plates of the

15   multilayer plate can no more bend nor glide in respect to each other because of the compression friction between plates and fixation devices, like screws, which have been applied into the drill holes. In this case the multilayer plate, which is constructed of

20   thin, flexible plates, functions like a thick and stiff bended plate giving an efficient fixation for the bone fracture.

The invention will be hereafter described in more

25   detail with simultaneous references to the accompanied drawings, in which

Fig. 2a-d    shows schematically the steps of the fixation of the plate according to first

30   embodiment of the invention,

Fig. 3a-d    shows schematically an alternative way of the steps of the fixation of the plate according to first embodiment of the

35   invention,

Fig. 4a-d    shows schematically the second embodiment of the invention with oblong holes,

Fig. 5a-d shows schematically yet another alternative way of the steps of the fixation of the plate according to first embodiment of the invention,

Fig. 6 shows schematically in a perspective view the different orientation of reinforcement elements in separate plates according to one alternative embodiment of the invention and

Fig. 7 shows a cross-sectional view of the embodiment of the invention used in connection with experiments of Example 2.

Figure 2 shows a side view in cross-section of a typical embodiment of the invention. A bundle 5 of four relatively thin, flexible plates is bent on the uncovered bone surface 6 over the fracture 3 (Figure 2a) and the bundle of the plates is fixed temporarily on the bone surface with metallic clamps 7 (Figure 2b). A suitable amount of holes 8 is drilled on the both sides of the fracture through the multilayer plate (or plate bundle) and through bone (Figure 2c). The multilayer plate 5 is fixed to the bone by means of screws 4 which are driven into the drill holes 8. The screws are typically driven through the back cortex to obtain strong fixation. The temporary clamps are removed (Figure 2d) and the uncovered bone surface can be covered with soft tissues. The reduction of the fracture is retained exact, because the single plates of the multilayer plate cannot glide in relation to each other.

According to another advantageous embodiment (Figure 3) the multilayer plate 5 can be first fixed with one screw 4, with bolt, rivet, clamp or corresponding, to

the surface of the uncovered bone through one drill hole (Figure 3a). Thereafter the multilayer plate can be fixed stepwise on the bone surface by bending the multilayer plate on the bone surface by fixing it temporarily with a metallic clamp 7, by drilling another hole 8 for the second screw through the multilayer plate and bone (Figure 3b) and by tightening the multilayer plate also through this hole on the bone by a screw. Now the clamp can be loosened (Figure 3c). The surgeon proceeds over the whole multilayer plate with this technique and as a consequence the multilayer plate will be fixed tightly on the bone (Figure 3d). It is self-evident that other versions of fixation techniques are possible for fixation of the multilayer plate of the invention on the bone.

According to an advantageous embodiment the plates of the multilayer plate can have elongated holes. Figure 4a shows schematically a plan view from above one such plate of the multilayer plate with its elongated holes 9. When a bundle of this kind of plates is stacked on the bone surface, the fixation holes can be drilled directly into the bone through the elongated holes and the multilayer plate can be fixed with screws or other fixation elements on the bone. After tightening of the screws the plates cannot glide any more in relation to each other. This situation has been described schematically from above in Figure 4b, where the topmost plate 5' of the multilayer plate bridging the fracture 3 of the bone 6. The fixation screws 4 going through the elongated holes 9 are also seen.

With the multilayer plate of the invention one can create also compression into the bone fracture according to the following principles:



The multilayer plate is fixed with metallic clamps on the bone surface over the fracture in such a way that a good mutual contact between bone fragments, and between multilayer plate and bone is retained. The multilayer plate is fixed on bone first with one fixation device (e.g. with a screw according to Figure 3a). On the same side of the fracture additionally necessary amounts of screws is fixed (e.g. 2-3 additional screws). Figure 5a shows schematically from above the situation, where the multilayer plate 5 (whose uppermost plate 5' is seen) has been fixed on the bone 6 on the other side of the fracture 3 with three screws 4, 4', 4". The screws have been installed in the middle of the holes of the multilayer plate so that every screw acts as a so-called neutral guide.

After this one relatively large hole 10 (Figure 5b) is drilled through the multilayer plate on the other side of the bone fracture. Through this hole another smaller eccentric hole 11 is drilled so that the middle point of this smaller drill hole is further away from the fracture than the middle point of the larger drill hole (Figure 5b). This situation is examined schematically in the enlarged Figure 5c. After this the surgeon drives into the drill hole 11 a screw 4 equipped with a conical head, as is shown schematically in Figure 5d from above. The screw 4 creates the compression effect (the compression of fractured bone parts against each other). The compression effect can be increased by using also another compression screw. Additionally one can generally use at least one neutral screw also on this other side of the fracture.

35

The compression effect can also be caused by designing the holes of the multilayer plate eccentric by other ways and/or by using suitable auxiliary devices which

cause compression. Different kinds of compression techniques are well-known in surgical techniques. They have been introduced e.g. in the book F. Séquin and R. Texhammar, "AO/ASIF Instrumentation", Springer, Berlin, 1981.

The single plates of the multilayer plate of this invention can be manufactured of biostable and/or absorbable polymer, polymer mixture, copolymer or polymer composite. For example following absorbable polymers given in Table 1 can be used for manufacturing of the devices of this invention:

Table 1. Absorbable polymers

- 5 Polyglycolide (PGA)
- Copolymers of glycolide:  
 Glycolide/L-lactide copolymers (PGA/PLLA)  
 Glycolide/trimethylene carbonate copolymers (PGA/TMC)
- 10 Polylactides (PLA)
- Stereocopolymers of PLA:  
 Poly-L-lactide (PLLA)  
 Poly-DL-lactide (PDLA)
- 15 L-lactide/DL-lactide copolymers
- Copolymers of PLA:  
 Lactide/tetramethylglycolide copolymers  
 Lactide/trimethylene carbonate copolymers  
 20 Lactide/ $\delta$ -valerolactone copolymer  
 Lactide/ $\epsilon$ -caprolactone copolymer  
 Polydepsipeptides  
 PLA/polyethylene oxide copolymers  
 Unsymmetrically 3,6-substituted poly-1,4-dioxane-2,5-  
 25 diones
- Poly- $\beta$ -hydroxybutyrate (PHBA)  
 PHBA/ $\beta$ -hydroxyvalerate copolymers (PHBA/HVA)
- 30 Poly- $\beta$ -hydroxypropionate (PHPA)  
 Poly-p-dioxanone (PDS)  
 Poly- $\delta$ -valerolactone  
 Poly- $\epsilon$ -caprolactone  
 Methylmethacrylate-N-vinyl pyrrolidine copolymers
- 35 Polyesteramides  
 Polyesters of oxalic acid  
 Polydihydropyrans  
 Polyalkyl-2-cyanoacrylates  
 Polyurethanes (PU)
- 40 Polyvinylalcohol (PVA)  
 Polypeptides  
 Poly- $\beta$ -malic acid (PMLA)  
 Poly- $\beta$ -alkanoic acids  
 Polyvinylalcohol (PVA)
- 45 Polyethyleneoxide (PEO)  
 Chitine polymers

Reference: S. Vainionpää, P. Rokkanen and P. Törmälä,  
 50 Progr. Polym. Sci., in press.

It is self-evident that also other absorbable polymers than those given in Table 1 can be applied in manufacturing the devices or their parts of this invention. E.g. the following publications give

5 absorbable (biodegradable) polymers which can be applied in this connection: U.S. Pat. No. 4 700 704 (Jamiolkows and Shalaby), U.S. Pat. No. 4 653 497 (Bezwada, Shalaby and Newman), U.S. Pat. No. 4 649 921 (Koelmel, Jamilkows and Bezwada), U.S. Pat. No.

10 4 559 945 (Koelmel and Shalaby), U.S. Pat. No. 4 532 928 (Bezwada, Shalaby and Jamiolkows), U.S. Pat. No. 4 605 730 (Shalaby and Jamiolkows), U.S. Pat. No. 4 441 496 (Shalaby and Koelmel), U.S. Pat. No. 4 435 590 (Shalaby and Jamiolkows).

15

The multilayer plates of this invention, which are manufactured of polymer, polymer mixture or copolymer, are of their structure at best reinforced composites.

20 Absorbable composites, like self-reinforced absorbable composites, are specially advantageous raw-materials for manufacturing the multilayer plates of this invention. Such self-reinforced composites have been described in publications U.S. Pat. No. 4 743 257

25 (Törmälä et al.) and WO88/05312 (Törmälä et al.).

Also other types of absorbable composites can be applied in manufacturing of the multilayer plate of this invention. Accordingly multilayer plates can be manufactured by reinforcing absorbable material with

30 fibers, film fibers, filaments, etc. which have been manufactured of absorbable polymer, copolymer or polymer mixture. The reinforcing can be carried out also with structures which have been constructed of above reinforcing elements like with braids, threads,

35 bands, non-woven structures, fabrics, knits etc. The reinforcing with the above reinforcing elements is made by combining the reinforcing elements and the

- absorbable polymer matrix with each other applying typical polymer technological methods. The reinforcing elements like absorbable fibers can be manufactured e.g. of several of the absorbable polymers given in Table 1 and in the above text. The fibers can also be biodegradable ceramic fibers, like e.g. calcium phosphate fibers (see e.g. S. Vainionpää et al., progr. Polym. Sci., in press).
- 10 The multilayer plates of the invention comprising absorbable organic and/or unorganic absorbable fibers or structures constructed of them and absorbable matrix, can be manufactured with various methods of plastics technology by winding the reinforcing structures at least partially to each other with absorbable polymer, copolymer or polymer mixture (matrix material) in such conditions, where matrix and reinforcing structures form homogeneous enough composite. Such structures are formed usually when the matrix is in liquid or melted state. Suitable methods to bind the reinforcing fibers etc. and matrix to each other and to form the composite material to semifinished products and/or implants are e.g. injection molding, extrusion, pultrusion, filament winding, compression winding and other plastics technological processing methods. The multilayer plate of the invention can also be manufactured of many biostable polymers, like polyethylene, polypropylene, polyacetal, polyamides, polyesters, polysulphone, polyetheretherketone, thermoplastic liquid crystalline polymers and other polymers.

Absorbable and/or biostable multilayer plate materials can also be reinforced with biostable fibers like with carbon fibers, ceramic fibers (e.g.  $\text{Al}_2\text{O}_3$ ), polyester fibers etc. It is natural that the devices of the invention can additionally include different kind of additives or auxiliary chemicals to facilitate

the processing of the material (e.g. stabilizers, antioxidants or plasticizers) or to change its properties (e.g. plasticizers or powder-like ceramic materials or biostable fibers like carbon fibers) or  
5 facilitate its handling (e.g. colours).

According to an advantageous embodiment the devices of the invention include some bioactive material or materials, like antibiotic, chemotherapeutic, chemicals  
10 accelerating the healing of the wound, growth hormones, anticoagulants (like heparine) etc. This kind of bioactive devices are especially advantageous in clinical use, because they have in addition to the mechanical effect also biochemical, chemotherapeutic,  
15 drug effect etc. in living tissues.

The fixation device of the invention has several advantages in comparison the known plate-like devices. The polymeric or polymer composite plate do not have  
20 the adverse corrosion effects of metal plates and the elastic modulus of the polymer or polymer composite plate can be regulated suitably in such a way that the porosity of the bone does not increase and the healing of the fracture occurs with the callus  
25 mechanism. A special advantage is that the drill holes of the devices of the invention can be done just in the operation room by drilling. In this way the drill holes can be tailormade into the plate in the best way for the treatment of the patient. A  
30 significant advantage of the multilayer plate of the invention in comparison to the known polymeric and composite plates is the fact that the multilayer plate of the invention can be bended easily without heating, which facilitates and simplifies the operation  
35 and gives an exact operational result.

The multilayer plate is also tougher than one thick polymer plate. The thick absorbable polymer plates

have a tendency of breaking (see e.g. J. Eitenmüller  
et al. Abstracts of Eur. Congr. Biomater., Bologna,  
Italia, 1986, p. 94). Example 1 of this invention shows  
that the multilayer plates did not break in animal  
5 test. A evident reason to this is that the thin plates,  
about which the multilayer plate is constructed, are  
tougher than the thick plates. On the other hand, if  
a fracture nucleates in one plate of the multilayer  
plate, it does not necessarily lead to catastrophal  
10 fracture of the whole device as easily as a nucleated  
fracture in a thick homogeneous plate.

The multilayer plate of the invention can be applied  
in fixation of different kinds of bone fractures,  
15 osteotomies and arthrodeses.

It can also be applied for fixation of different  
kinds of prostheses like synthetic ligaments or  
ligament transplants or for fixation of other tissues  
20 into or on bone tissue by locating at least part of  
the ligament, tissue etc. between the plates of the  
multilayer plate and/or between the bone tissue and  
the multilayer plate.

25 One special advantage of the multilayer plate of the  
invention in comparison to the known plates is that  
surgeon can manufacture the multilayer in operation  
room taking into account the size of the bone and/or  
the fracture of the patient. The multilayer plate can  
30 be easily constructed in operation room by cutting  
suitable parts from bigger polymer- or composite  
plate e.g. with scissors, stamping device, cutter,  
saw, hot wire, laser cutter etc. other cutting device  
desirable plates and by combining them to a multilayer  
35 plate (plate bundle) of the invention. By using such  
tailormade multilayer plates it is possible to optimize  
the fixation effect and at the same time to minimize  
the foreign material amount which is impanted into

the tissues of the patient. Therefore this invention describes also a methos to manufacture the multilayer plate according to needs of the patient and of the trauma. This methos is characterized by that the  
5 single plates of the multilayer plate are manufactured of a bigger plate by processing of it smaller parts which are suitable for the treatment of the bone fracture.

10 Single plates of the multilayer plate of the invention can be fixed to each other with a binding material layer which is very elastic or easily deformable with plastic deformation. This makes the treatment of the multilayer plate in operation room easier when the  
15 single plates have been bound to each other. When this kind of multilayer plate is bent on the bone surface according to its surface curvature, the binding material layer deforms (elastic or plastic deformation) which facilitates the gliding of the single plates to  
20 each other giving at last for the multilayer plate the desired shape. Suitable binding materials to the above multilayer plate are flexible and soft polymers, e.g. -caprolactone and its copolymers (e.g. with lactide), ethylene oxide-lactide copolymers, amorpjous  
25 lactides like poly-DL-lactide. It is natural that also other types of elastic or plastic polymers or waxy oligomers etc. can be applied as binding material.

When the multilayer plate of the invention is  
30 manufactured of oriented and/reinforced plates, the different plates can be manufactured of materials oriented and/or reinforced in different directions. In this case a multilayer plate structure, which is strong in different directions can be constructed.  
35 The structure of such a multilayer plate has been schematically in Figure 6 where the orientation of molecular chains and/or the orientation of reinforcement elements (like reinforcing fibers) in



different single plates 5' of a multilayer plate has described with black lines 12.

5 The invention and its function has been illustrated in details with the following examples.

EXAMPLE 1.

10 The fixation of the osteotomy of sheep mandibula with polylactide plates.

15 Polylactide plates with the thickness 2.0 mm and other dimensions 50 x 50 mm were manufactured by injection molding from poly-L-lactide (Mw 250.000, manufacturer CCA biochem, Holland). The plates were drawn at 90°C to the final thickness of 0.5 mm. The plates self-reinforced during the drawing. The drawn plate was cut in the drawing direction to 60 mm long and 12 broad plates. Four such plates were stacked on 20 each other to form a multilayer plate. The plates were sterilized by immersing them for 5 minutes in ethanol/water (75 w/w-% of ethanol) mixture.

25 A sheep was anesthetized. The skin area on the right side of mandibular was shaved and washed with Neo-Amisept. The skin was opened and the periosteum of mandibula was revealed. The diastema area of mandibula was revealed and the mandibula was osteotomised in this area. The cut part of mandibula was fixed 30 temporarily from the upper part of the bone with a fracture clamp. The bone tissue was dissected free of soft tissues 3 cm to both sides of the osteotomy. A 0.5 mm thick, 12 mm broad and 60 mm long self-reinforced polylactide plate was located on the 35 dissected area so that the middle point of the plate was above the osteotomy. Three identical plates were stacked on this first plate by hand and the plates were bent according to the form of the bone. The

multilayer plate comprising four single plates was fixed with plate clamps to the both pieces of mandibula so that a good contact of the osteotomized fragments remained. A 2.5 mm diameter drill hole was drilled through the multilayer plate to the end of the plate near the condyle. Through this drill hole a 2 mm diameter drill hole was drilled into the bone through both cortexes. This drill hole was drilled in the middle of the bigger hole in the multilayer plate (neutral guide). The length of the drill hole in bone was measured and it was threaded. A 2.5 mm diameter titanium screw was driven into the bone so that the multilayer plate was now fixed with one screw on the mandibula. Altogether three drill holes were done into the condylar part of the multilayer plate and into every drill hole one screw with the above given neutral technique was fixed. On the other side of the osteotomy a 3.2 mm diameter drill hole was drilled through the multilayer plate near the osteotomy and an eccentric drill hole (2.0 mm diameter) was drilled with an eccentric guide into the bone through both cortexes in such a way that the middle point of the drill in the bone was 0.8 mm further from the osteotomy line than the middle point of the drill hole in the multilayer plate. A titanium screw was driven into the drill hole in the bone so that the screw created 0.3 mm compression effect into the plate; first the screw was not driven totally to the end, because also the following (second screw) was fixed with the same technics. Accordingly two eccentric screws were applied to create the compression effect (it should have been possible also to use only one eccentric screw). Also this second part of the multilayer plate (on the distant side of the osteotomy in relation to the condyle) was fixed altogether with three screws so that one screw was fixed with the neutral guide principal. With this technique it was possible to fix the multilayer plate on the bone surface so that the

multilayer plate followed the form of the bone and the screws in the drill holes of the multilayer plate prevent it from straightening. So the multilayer plate fixed the osteotomy steadily with the slight compression. Subcutaneous tissue and the skin were closed with absorbable suture (Dexon). After the operation the sheep got for one week liquid-like food. Altogether 14 sheep were operated with the above technics. X-ray figures were taken from all osteotomies after three weeks. Three animals were sacrificed 6, 12 and 24 weeks after operation and the mandibulas were reprepared carefully, x-ray figures were taken from mandibula and the bone was cast into methylmethacrylate. Histological observations showed that ossifying of the osteotomies was in progress after six weeks and after 12 weeks all the osteotomies were ossified. After one and two years' follow-up x-ray figures showed normal ossifying. Histological study from one mandibula afetr two years' follow-up time showed that the biodegradation of polylactide plates had started.

A comparative study was done with one sheep, for which the osteotomy was fixed with one injection molded 2 mm thick PLLA plate (breadth 12 mm, length 60 mm, fixation with 6 titanium screws). Six weeks after operation the plate had broken around two fixation screws and the osteotomy did not ossify, but a connective tissue bridge was formed.

#### EXAMPLE 2.

The following polymers were applied to manufacture by injection molding 2 x 60 x 80 big plates: poly-L-lactide, polyglycolide, poly- $\beta$ -hydroxybutyrate, glycolide/lactide copolymer (Polyglactine 910), HD-polyethylene, polypropylene, HD-polyethylene+polypropylene mixture (mole ratio 1:1), polysulphone,

polyetheretherketone. The plates were to the thickness of 0.5 mm at temperatures  $T = T_g + (10-60^\circ\text{C})$ , where  $T_g$  = the glass transition temperature of the polymer. The drawn plates were cut in the drawing direction to 70 mm long and 10 mm broad plates. All such cut plates were stacked on each other to form a multilayer plate. Six drill holes with a distance of 10 mm between single drill holes were drilled through the multilayer plate with a 2 mm diameter drill. Threaded bolts 13 with the diameter of 2.2 mm were driven into the holes and the multilayer plate comprising of four single plates were tightened to tight bundles by driving nuts 14 (see Figure 7) to the other ends of the bolts and by tightening the nuts. The bending strengths of the multilayer plates fixed with bolt were compared with the bending of corresponding single plates with dimensions 2 x 10 x 70 mm which were perforated and bolted in an analogous way. The bending strengths of the multilayer plates were 1.5 - 4 times higher than the bending strengths of the injection molded plates.

Claims:

1. A plate for fixation of a bone fracture,  
5 osteotomy, arthrodesis or corresponding or for fixation  
of a ligament, tendon or connective tissue on the  
bone, said plate being intended to be fixed on the  
bone at least with one fixation device like screw,  
rod, clamp or corresponding, characterized in  
10 that the plate comprises at least two essentially  
superimposed plates, so as to provide a multilayer  
plate construction, in which the plates have been  
manufactured of a polymer copolymer, polymer alloy or  
polymer composite and that the individual plates of  
15 said multilayer plate construction are flexible so as  
to provide a change of form of said multilayer plate  
construction to substantially assume the shape of the  
bone surface in the operation conditions by means of  
an external force directed to said multilayer plate  
20 construction, whereby each individual plate assumes  
the position of its own with respect to other  
individual plates by differential motion along the  
surfaces of coinciding plates.
- 25 2. A plate according to Claim 1, characterized  
in that the individual plates have been joined to  
each other by means of an intermediate layer between  
the surfaces of the coinciding plates to allow the  
differential motion of the individual plates of said  
30 multilayer construction e.g. the gliding of the plates  
in respect to each other in operation conditions.
3. A plate according to claims 1 and/or 2,  
characterized in that the individual plates are  
35 locked with respect to each other to accomplish a  
substantially stiff multilayer plate construction by  
means of frictional force between the individual  
plates, said frictional force being accomplished by

the effects of said at least one fixation device during the fixation of said multilayer plate construction on the bone surface.

5     4.     A plate according to any claim of claims 1-3,  
characterized     in that said multilayer plate  
construction is provided with at least two holes  
through each individual plate of said multilayer  
10     plate construction, the diametral measure of said  
holes being at least in one diametral direction greater  
than the greatest diametral measure of the part of  
the fixation device to be positioned through said  
hole thus providing a certain dislocation between the  
15     holes in the individual plates with respect to each  
other without the risk that said hole through said  
multilayer plate construction becoming unable to  
receive said fixation device.

20     5.     A plate according to any claim of claims 1-4,  
characterized     in that said multilayer plate  
construction is provided with at least two oblong  
holes through each individual plate of said multilayer  
plate construction the direction of the oblongness  
25     being arranged preferably substantially in a direction  
allowing the maximum differential motion between said  
individual plates.

30     6.     A plate according to any claim of claims 1-5,  
characterized     in that at least part of said  
individual plates of said multilayer plate construction  
has been manufactured of biostable polymer.

35     7.     A plate according to any claim of claims 1-6,  
characterized     in that at least part of said  
individual plates of said multilayer plate construction  
have been manufactured of absorbable polymer.

8. A plate according to any claim of claims 1-6, characterized in that at least part of said individual plates of said multilayer plate construction have been reinforced with biostable reinforcing elements, like fibers or structures which have been constructed of fibers.

9. A plate according to any claim of claims 1-8, characterized in that at least part of said individual plates of said multilayer plate construction have been reinforced with absorbable reinforcement elements, like with fibers or structures constructed of fibers.

10. A plate according to any claim of claims 1-9, characterized in that at least part of said individual plates of said multilayer plate construction are self-reinforced.

11. A plate according to any claim of claims 8-10, characterized in that said reinforcement elements and/or the molecular chains in the separate individual plates of said multilayer plate construction are orientated in different directions.

12. A method for manufacture a plate of any claim of claims 1-11, characterized in that the individual plates of the multilayer plate construction are processed from a bigger plate (a plate preform) by cutting of it smaller, tailormade size parts suitable for the treatment of patient, by using suitable cutting method like scissors, stamping, cutter, hot wire, laser cutter, by sawing or with some other corresponding method.

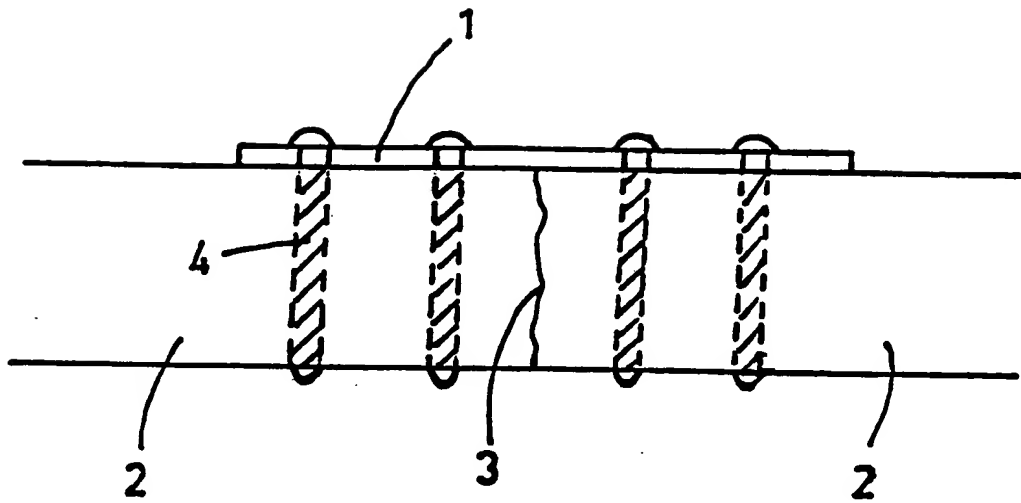
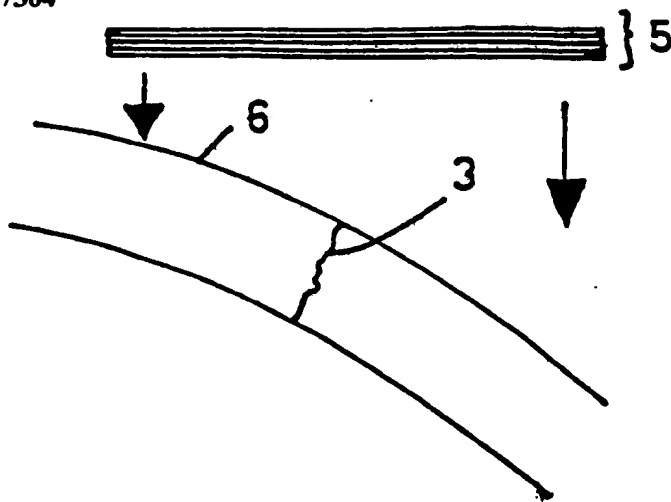
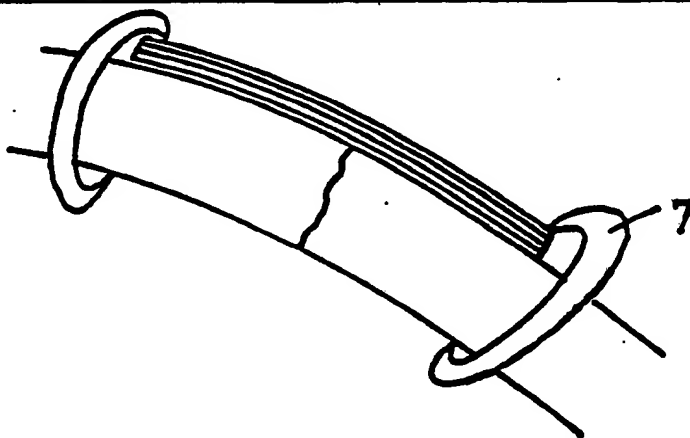


FIG 1

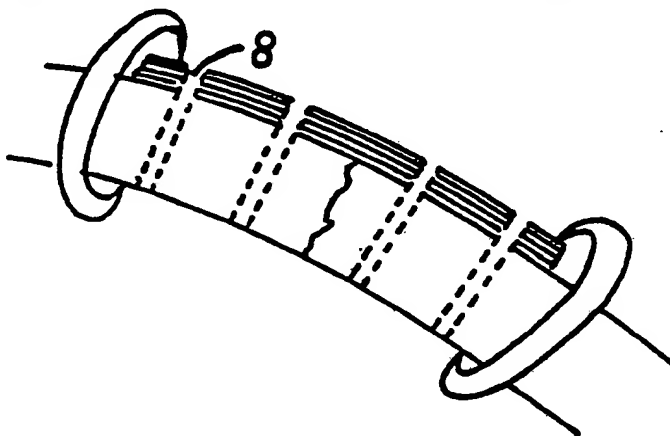




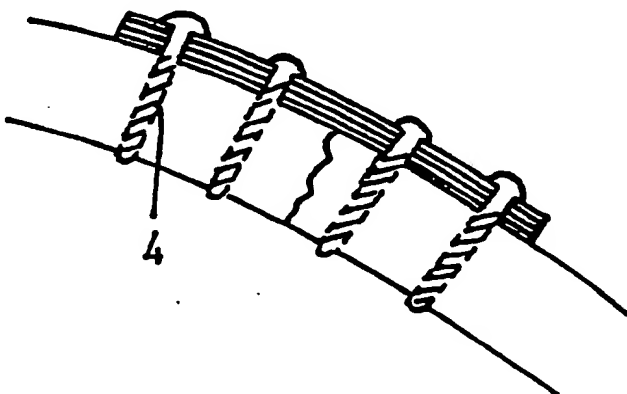
(a)



(b)

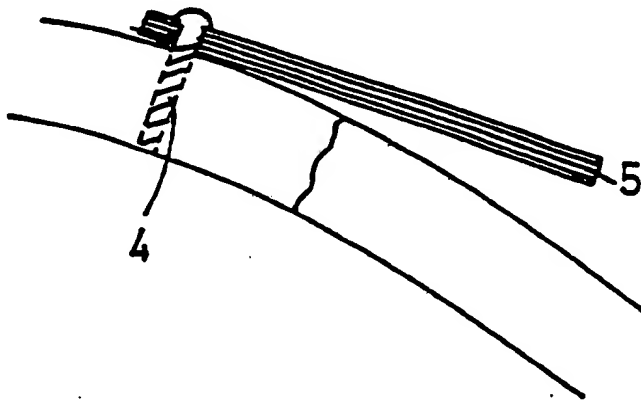


(c)

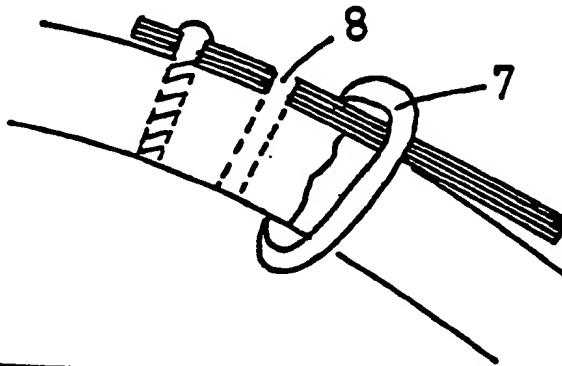


(d)

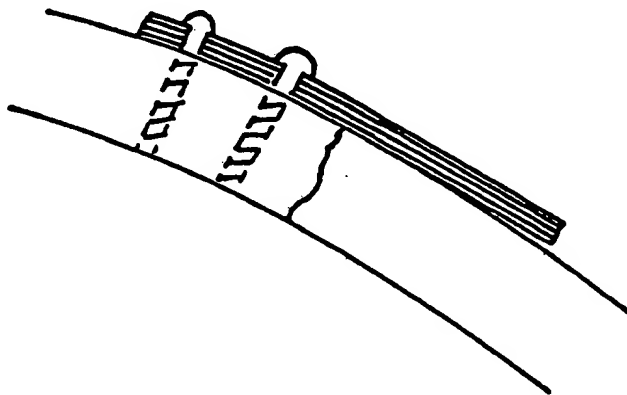
FIG 2



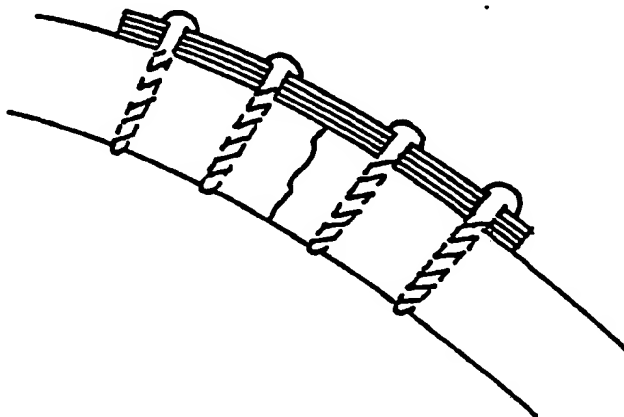
(a)



(b)

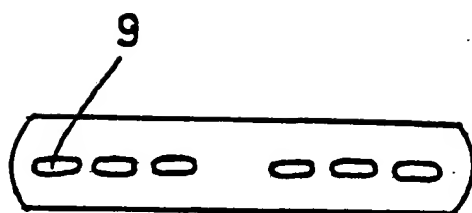


(c)

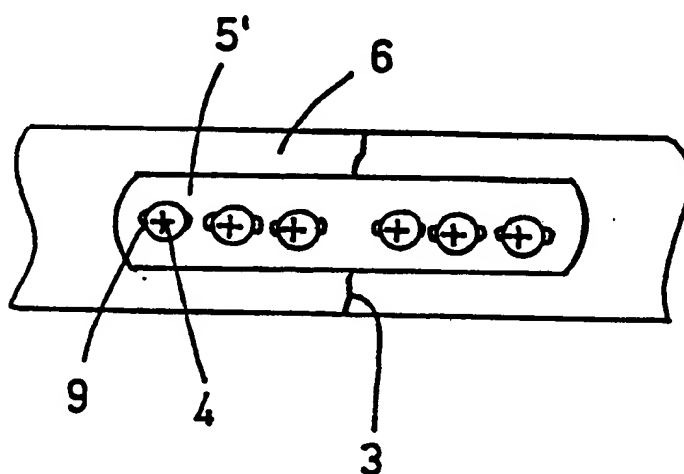


(d)

FIG 3



(a)



(b)

FIG 4

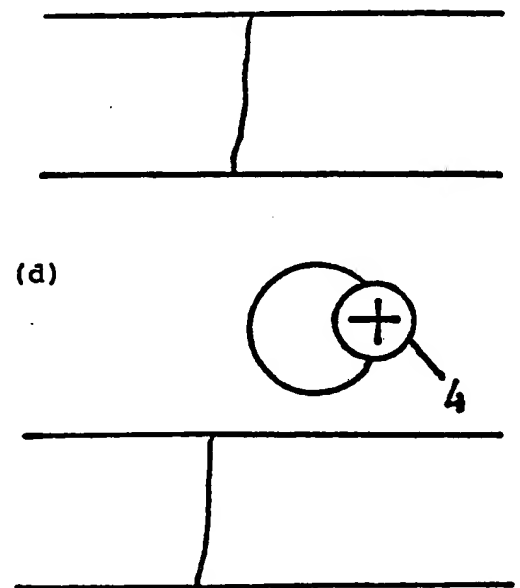
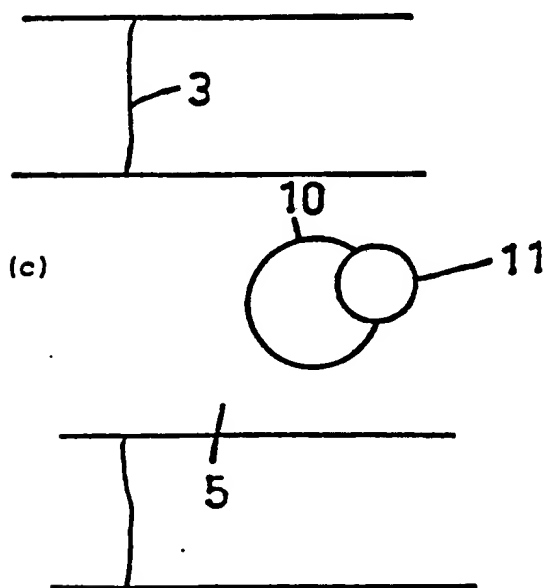
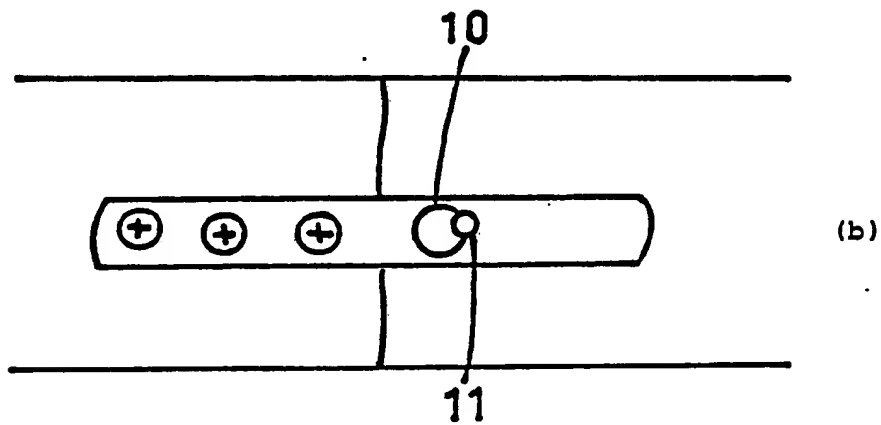
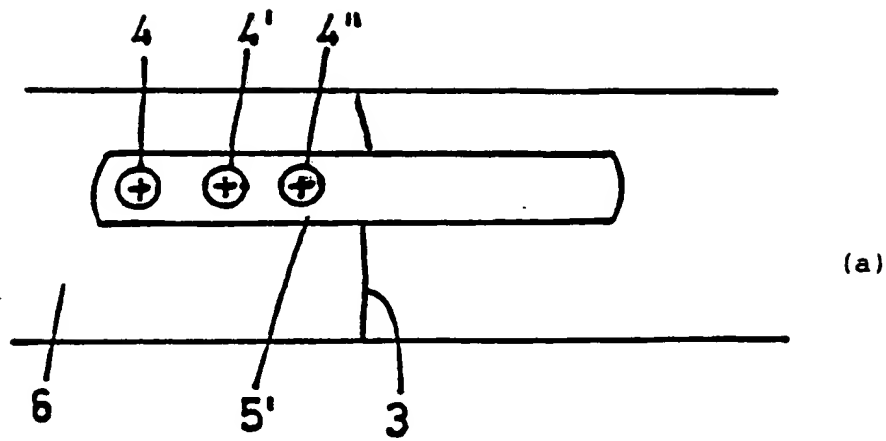


FIG 5

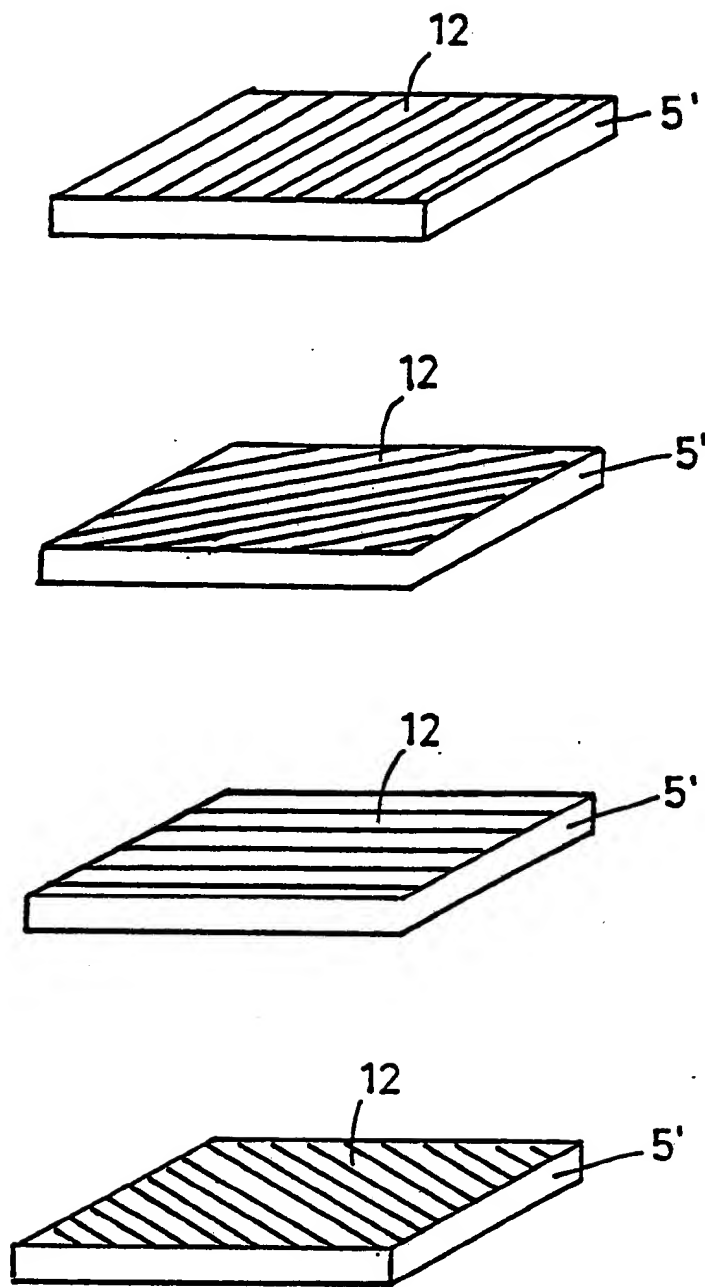


FIG 6

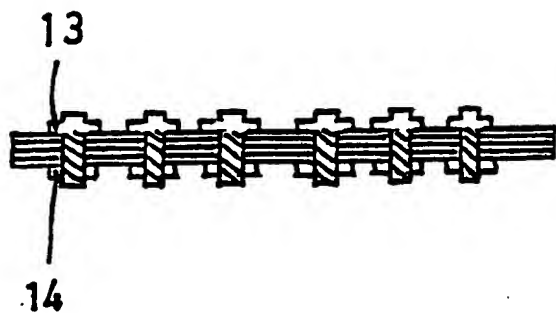


FIG 7

# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/FI 89/00236

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) \*

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: A 61 B 17/58

## II. FIELDS SEARCHED

Minimum Documentation Searched \*

Classification System 1

Classification Symbols

IPC5

A 61 B

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are included in the Fields Searched \*

SE,DK,FI,NO classes as above

## III. DOCUMENTS CONSIDERED TO BE RELEVANT \*

Category *	Citation of Document, ** with indication, where appropriate, of the relevant passages **	Relevant to Claim No. 13
A	EP, A2, 0149540 (ED. GEISTLICH SÖHNE A.G) 24 July 1985, see page 6, line 35 - page 7, line 9; figures 1-2 --	1
A	US, A, 4338926 (KUMMER ET AL) 13 July 1982, see abstract; figures 1-3 --	1
A	WO, A1, 88/05312 (TÖRMÄLÄ ET AL) 28 July 1988, see abstract; figures 1-6 -- -----	

\* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"A" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

26th March 1990

Date of Mailing of this International Search Report

1990 -03- 29

International Searching Authority

SWEDISH PATENT OFFICE

Signature of Authorized Officer

Hans Peterson

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO. PCT/FI 89/00236**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A2- 0149540	85-07-24	JP-A- 60227762 US-A- 4773406	85-11-13 88-09-27
US-A- 4338926	82-07-13	CA-A- 1166108 EP-A-B- 0052998 JP-A- 57117852	84-04-24 82-06-02 82-07-22
WO-A1- 88/05312	88-07-28	NONE	